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ARTICLE TITLE

Ecosystem services, environmental stressors and decision making: How far have we got?

RUNNING HEAD

Ecosystem services, stressors and decision making

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Explicit consideration of the benefits that humans receive from ecosystems, commonly called ecosystem services, has the potential to improve environmental management decision making. The importance of ecosystem services to human well-being was highlighted by the Millennium Ecosystem Assessment (MEA 2005) and in 2009 Daily et al. proposed a conceptual framework and sketched out a strategic plan for delivering on the promise of ecosystem services: that is increasing the recognition of environmental benefits in decision making. This paper, along with others published around the same time (Fisher et al. 2009; De Groot et al. 2010), raised a number of challenges that had to be addressed to mainstream the ecosystem services approach into environmental decision making. These challenges included: understanding the provision of ecosystem services; understanding the value of services; developing metrics and methods for quantifying the production and flows of ecosystem services; and developing models and methods for predicting how particular decisions will affect ecosystem services.

Five years on, how far have we got in addressing these challenges and what are the outstanding issues? A joint Pellston Workshop, organised by the Society of Environmental Toxicology and Chemistry (SETAC) and the Ecological Society of America (ESA), was held in Shepherdstown, West Virginia, USA, from September 28 to October 3, 2014 to address these questions. Building on previous SETAC and ESA activities on ecosystem services (e.g. Daily et al. 1997, Stahl et al. 2009, Van Wensem and Maltby 2013), the workshop drew on the strengths of the SETAC and ESA communities to bring together 29 key thinkers from industry (10), academia/NGOs (9) and government (10) from Europe (11) and central/north America (18) to review progress in applying the ecosystem services concept to risk assessment and natural resource management. All participants were invited based on their expertise as individual scientists. The focus was on environmental stressors – defined broadly to include chemical,

physical and biological drivers of change in ecosystems. The objective of the Pellston Workshop was to develop consensus about, and practical guidance for, the application of the ecosystem services concept to stressor risk assessment and environmental decision making as part of a movement towards sustainability. Discussions about ecosystem services centered on current and potential applications in setting protection goals, ecological production functions, inclusion in risk assessment, and use in natural resource management and restoration activities. Each of these four themes was developed in separate workgroups and discussed with all participants in plenary sessions. The outcomes of these discussions are presented in this special issue and key findings are summarised below.

The general presumption is that ecosystem services approaches improve environmental decision making as they make the connections between ecosystem properties and process and human well-being explicit. But is there evidence for this? Van Wensem et al. (this issue) identified three criteria that characterise ecosystem services approaches: connects impacts all the way from ecosystem changes to changes in human well-being; considers all relevant ecosystem services affected by the decision; considers and compares the changes in well-being of different stakeholders. They illustrated the application of these criteria using case studies at different spatial scales and from different jurisdictions, and concluded that ecosystem services approaches were generally compatible with environmental policy and decision making at scales from supranational to local. However, whereas six of the seven case studies met at least 2 of the 3 criteria, only one met all three criteria in full. Most case studies did not include an explicit consideration of how different stakeholders were affected by a decision. Van Wensem et al. (this issue) recommend the wider application of these criteria as part of a rigorous test of the general

hypothesis that ecosystem services approaches improve decision making with regards to the protection of natural resources.

One of the key challenges in using ecosystem services approaches to inform environmental decision making is translating environmental impacts on ecosystem structure and process to changes in ecosystem service delivery (Olander & Maltby 2014). Bruins et al. (this issue) addressed the use of ecological production functions (EPFs) to link effects of environmental stressors on receptors in ecosystems and multiple ecosystem service endpoints. It is clear from their analysis that, despite the important role of EPFs in environmental management and decision making, the limited availability of relevant datasets and poor understanding of critical linkages among ecological components delivering services is severely impeding the development and application of EPFs. Bruins et al. (this issue) argue that EPFs should ideally estimate final ecosystem services and that they are most useful for decision making if they are quantitative.

The central role of EPFs in incorporating ecosystem services in risk assessment and resource management was echoed by Munns et al. (this issue) and Moore et al. (this issue). Munns et al. (this issue) present a number of recommendations for developing risk assessment and management within an ecosystem services framework, which include clearly linking assessment endpoints to human health and well-being and selecting endpoints using approaches similar to those developed by EFSA (2010) and USEPA (Munns et al. 2015). ES assessment endpoints are viewed as being compatible with, and complementary to, conventional endpoints. Further, an ecosystem services approach provides a common currency that enables integration of human health and ecological risk assessments. The use of conceptual models is recommended to evaluate policy options, identify co-benefits and communicate risk and associated management

decisions. The outcome of the risk assessment should be communicated in a form that is amenable to valuation, and targeted monitoring should be used to evaluate the effectiveness of decisions and enable adaptive management.

Moore et al. (this issue) evaluated ecosystem-based natural resource management (ES-NRM) as a framework for informing decisions where changes in the provision of key ecosystem services can be assessed under alternate landscape and resource management scenarios. ES-NRM can be applied to: maintain or enhance existing service provision; restore service provision; transform degraded areas to provide alternative services; or replace lost services at an alternative location. An important consequence of applying an ES-NMR framework is the shift in focus from a limited number of ecosystem components deemed by risk assessors to be important to ecosystem structure and function to protection goals and assessment endpoints relevant to broad aspects of societal well-being. As such, the framework can provide a transparent approach for balancing economic, ecological and societal drivers in resource management decisions and for identifying the consequences and trade-offs that result from such decisions.

There has been considerable progress since the call to arms by Daily et al. in 2009. The workshop concluded that the ecosystem services approach is compatible with existing environmental policies, regulatory processes and assessment frameworks and that many of the tools to enable the application of an ecosystem services framework to risk assessment and resource management are currently available. An ecosystem services framework provides a mechanism for integrating across single stressor/single media environmental policies and for involving stakeholders in environmental decision making. As such it has the potential to deliver more holistic and effective environmental management at a landscape scale. However, the

workshop also identified the need for a robust test of the hypothesis that ecosystems services approaches improve decision making, change decisions and improve outcomes. Such an evaluation would inform the development and future use of the ecosystem services approach by highlighting successes, identifying barriers to acceptance and targeting integration into policy where it can be most effective. The lack of post-decision monitoring to evaluate the effectiveness of decision-making and to inform adaptive management was highlighted as a particular concern.

A recurring theme of the workshop was a recognition of the essential role that EPFs play in the translation of stressor exposure or management interventions to changes in ecosystem service delivery, coupled with a frustration with the limited availability of rigorous quantifiable EPFs. This must be addressed if ecosystem service thinking is to be fully incorporated into environmental management decisions, but it should not, in itself, be an argument for not applying an ecosystem services approach; qualitative approaches can be used.

The workshop addressed the implementation of ecosystem service approaches in risk assessment, resource management and decision-making from an environmental sciences perspective and did not focus on the value and valuation of ecosystem services. Valuation was considered as part of the broader context and different viewpoints on ecosystem service valuation and types of valuation methods were discussed. In addition to reflections in Munns et al. (this issue) and Moore et al. (this issue), these discussions resulted in three opinion pieces by workshop participants that outline the case for valuation of ecosystem services based solely on monetization (Calow 2015) versus inclusion of non-monetized values (Kapustka and McCormick 2015, Munns and Rea 2015).

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